

User's Guide

micro-line®

AD4-512/612

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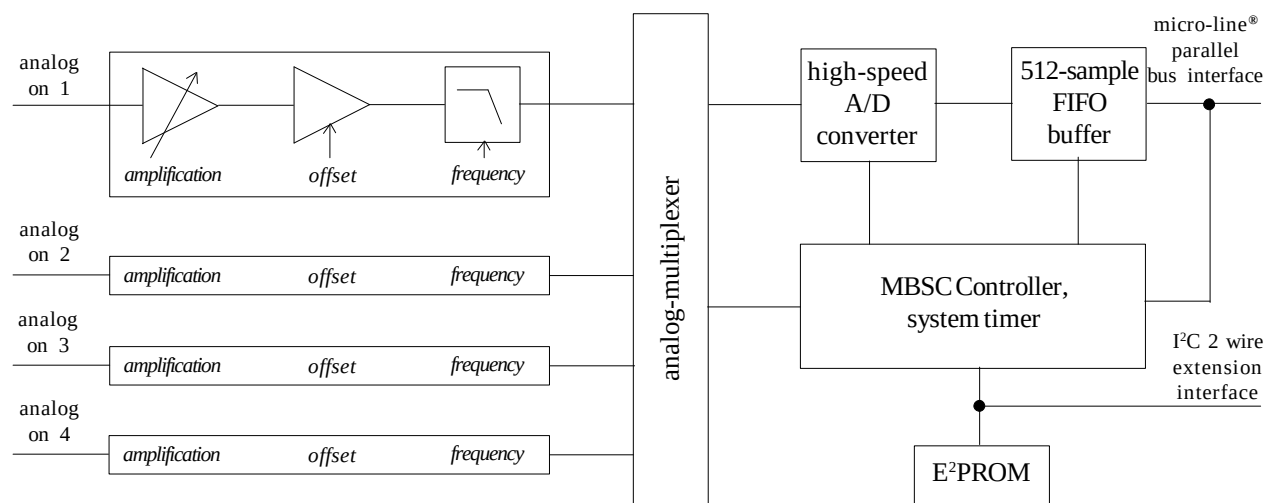
1. General

1.1 Introduction

The analog data system micro-line® AD4-612 is a high-performance, universal, and compact analog front/end platform offering many solutions for many different applications. ORSYS priority was to develop a high-performance and extremely user-friendly interface. This is, for instance, reflected in the fully programmable and on-board storable operation input timer parameters. Non-advantageous potentiometers are not required anymore. The result is a more efficient and considerably more compact system with less trouble-shooting.

The system is equipped with the micro-line® standard bus and can be connected with all micro-line® processor boards as a piggy-pack unit. The system can easily be connected with various microprocessor and microcontroller boards due to the exclusive use of standard bus signals. If this is the case, a peripheral standard unit needs to be connected with the signals D0...D15 (data), A0...A5 (addresses), /CS (chip-select), R/W (read/write), /STRB (strobe), /INT (interrupt) and /RESET. The supplied C-source code software drivers enable an operation with practically all common target hardware ANSI C-compilers for any target systems.

1.2 AD4-612 Block Diagramm



1.3 Analog Inputs

The analog data system AD4-612 has four differential analog inputs with a voltage range of -10V to +10V. The software-programmable, 12-bit pre-amplifier and offset pre-amplifier enable AD4-612 board operations in the input range of $\pm 10\text{mV}$ and $\pm 10\text{V}$ with any valid offset voltages. The input resistance per channel is 20 kOhm.

1.4 Anti-Alias Low-Pass Filter

The integrated Bessel low-pass filters are of 8th order and have an attenuation of 48 dB/Octave. The corner frequencies are software programmable and can be set from 0.1Hz to 50 kHz. There are additional solder bridges on the AD4-612 board in order to achieve higher corner frequencies >50kHz (200 or 100 kHz on channel 1, 100 kHz on channel 2 to 4). An alternative to the Bessel low-pass filters are the various Butterworth low-pass filters with higher order but transient disadvantageous behavior.

1.5 Multiplexer

The AD4-612 board is equipped with an 8-channel multiplexer which classifies the timing of the active channel to the appropriate analog part. The processing of the multiplexer is completely taken over by the MBSC (Multiple Burstmode Sampling Controller) and does not need to be performed by the application software. Channels 1 to 4 are active inputs, the additional channels 5 to 8 are locally connected test inputs with the following classification: +1.25V for channel 5, +2.5V for channel 6 and 0V for channels 7 and 8.

1.6 A/D Converter

The AD7892 is used as analog digital converter. It has a 12-bit resolution and operates with a sampling rate of up to 500kHz (version A) or up to 600kHz (version B).

1.7 FIFO-Buffer

The AD4-612 board is equipped with a 512 sample-wide FIFO buffer to improve the burst behavior and the interrupt capacity between the A/D converter and the connected processor. The interrupt triggering is programmable via software and can optionally be set to one sample or to 256 samples. This option optimises a minimum system reaction time or a minimum interrupt capacity.

1.8 Phase Optimized Sampling (POS)

With POS (Phase Optimized Sampling), samples of all high-speed channels (or a reduced, programmable number of channels) can be read in regular intervals and programmable breaks can be added until the procedure is re-started. This is important because the analog values of various input channels need to be read with minimum phase shifting. For example, the sample phase shifting of the different channels is only 1.7 % of the sampling rate if 4 channels are each sampled with 10 kHz.

1.9 Triggering

The Multiple Burst Mode Sampling Controller (MBSC) from ORSYS supports three types of board operations. In the Continuous Sampling Mode, the AD4-612 board operates continuously; in the Triggered Single Shot Burst Mode, a single burst is started with programmable length per external TTL trigger signal or by software triggering; and in the Auto Triggered Repeat Burst Mode, an automatic trigger repeat rate can be adjusted to control a cyclic burst repeat process. A separate TTL trigger signal is available for each board when several boards are operating synchronously.

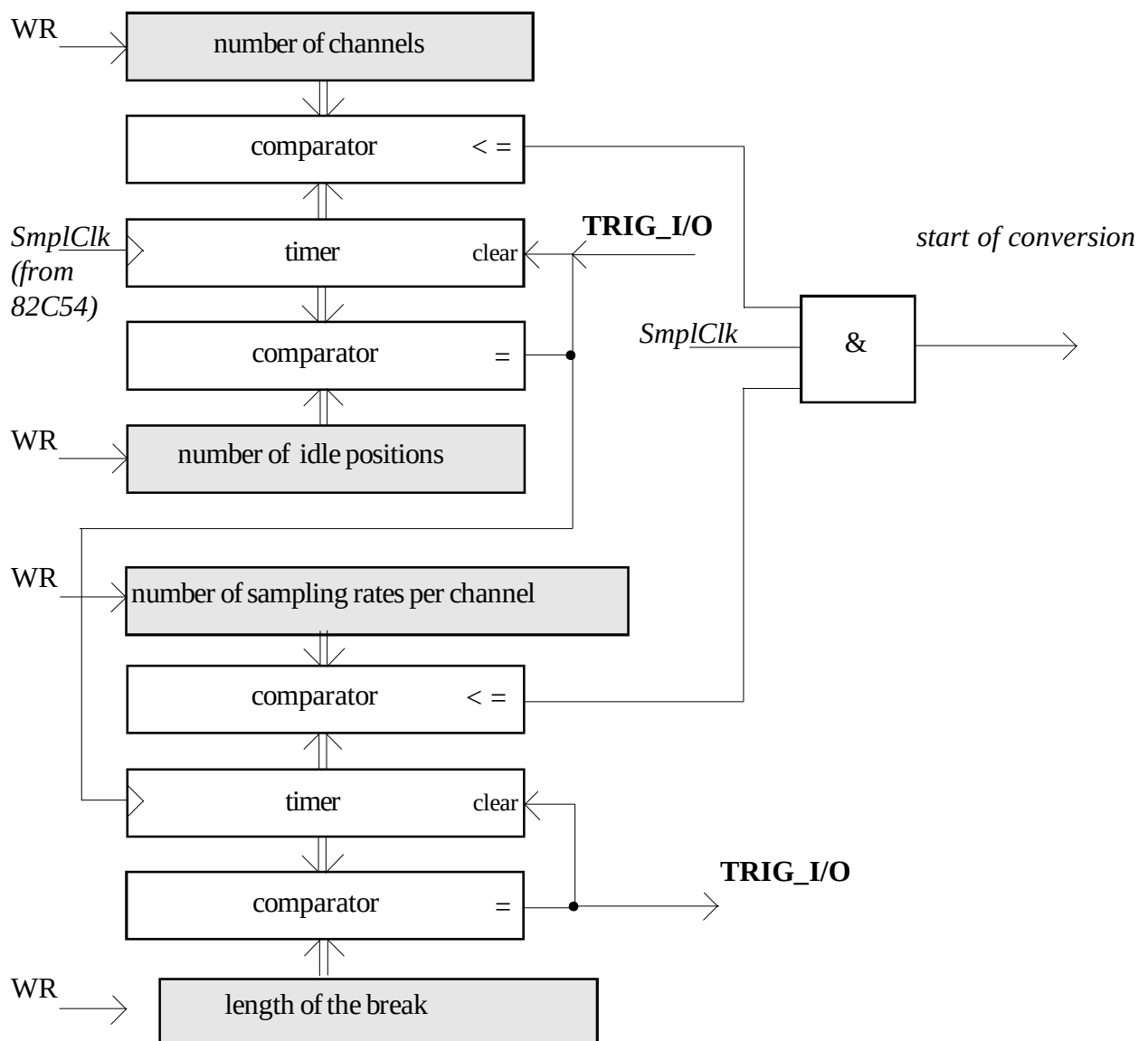
1.10 Synchronous Parallel Operation of Several Boards

Several AD4-612 boards can drive parallel and synchronously. Each board can be exactly parallel sampled by either one POS channel or by a large number of POS channels (with a sampling rate of up to 600kHz per channel). The synchronous operation of the AD4-612 board can generate a tremendous amount of data which is processed by several parallel operating processor systems. Thus, the number of possible processors and analog channels is virtually unlimited.

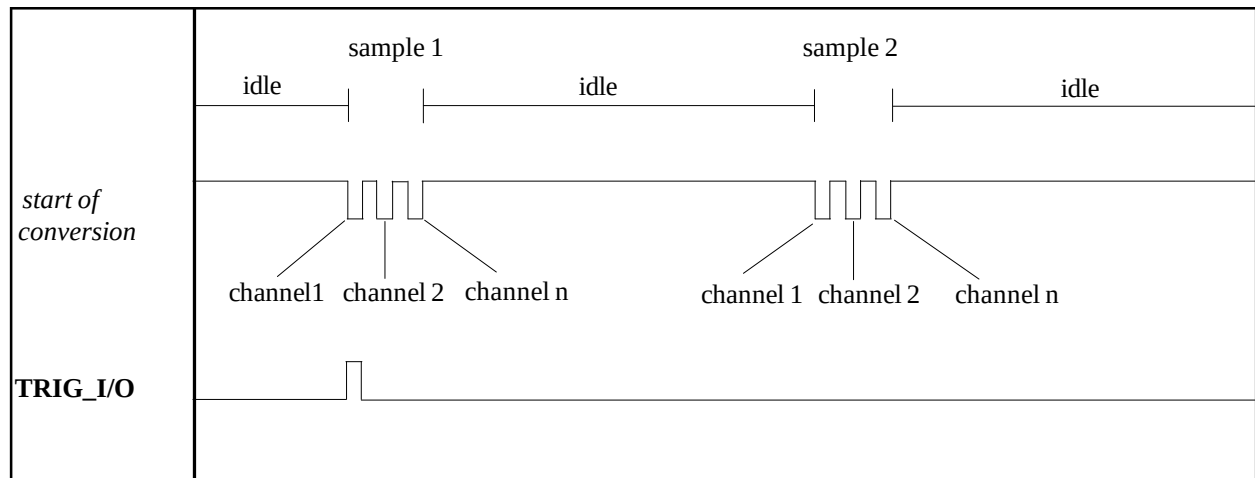
2. MBSC

The MBSC (Multiple Burstmode Sampling Controller) supports various trigger options, e. g., the Continuous Sampling Mode, Triggered Single Shot Burst Mode and Auto Triggered Repeat Burst Mode. The Continuous Sampling Mode continuously samples the preset number of channels. The Triggered Single Shot Mode samples a programmable number of values only once and then stops the sampling. The triggering can be generated by either the external signal **TRIG_I/O** or by the processor. The Auto Triggered Repeat Burst Mode and the Single Shot Mode sample a programmable number of values. After a programmable pause, the sampling automatically re-starts. A trigger signal synchronising this procedure, can also be generated by the external signal **TRIG_I/O** or by the processor. This is very important if several boards are operating in the parallel mode. Here, the virtually parallel Phase Optimized Sampling (POS) is always used. Phase Optimized Sampling allows the system to sample the input values of several channels with a minimum phase shift. Here, the initialized number of active channels is sampled with maximum speed and then idle states are added. One control register and four registers are available to set the operation modes which can be programmed via the processor. The sample clock *SmplClk* is set by the Timer 0 of the programmable timer module 82C54. The output signal of the MBSC is *Start Of Conversion* which controls the A/D converter. A value is sampled with every impulse of *Start Of Conversion*.

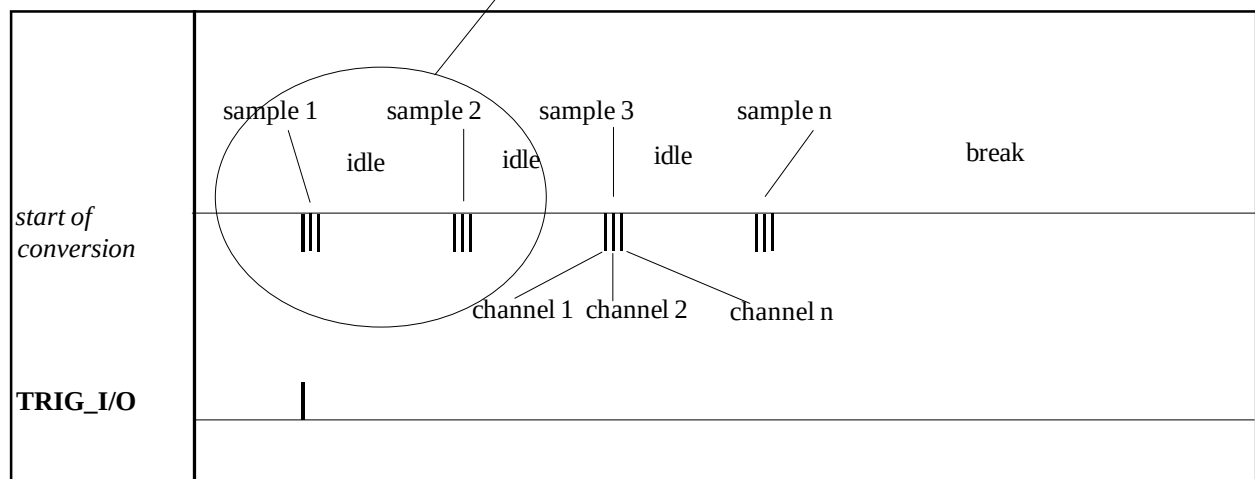
Block Diagram of the MBSC



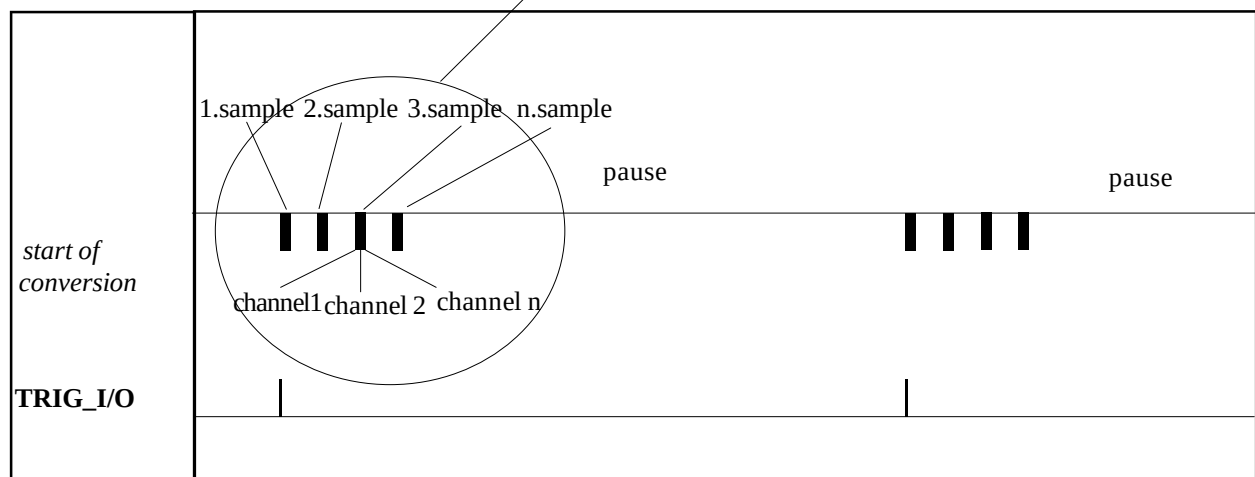
The MBSC triggers the *Start Of Conversion* impulse for each sample. For Phase Optimized Sampling (POS), the number of programmable channels is sampled one after another and then idle states are added. The following illustrations explain and show the differences between the **number of channels**, **number of idle states**, **number of samples** and **length of the pause** for the above-mentioned modes.



Continuous Sampling Mode



Triggered Single Shot Burst Mode



Auto Triggered Repeat Burst Mode

3. Operation of the AD4-612

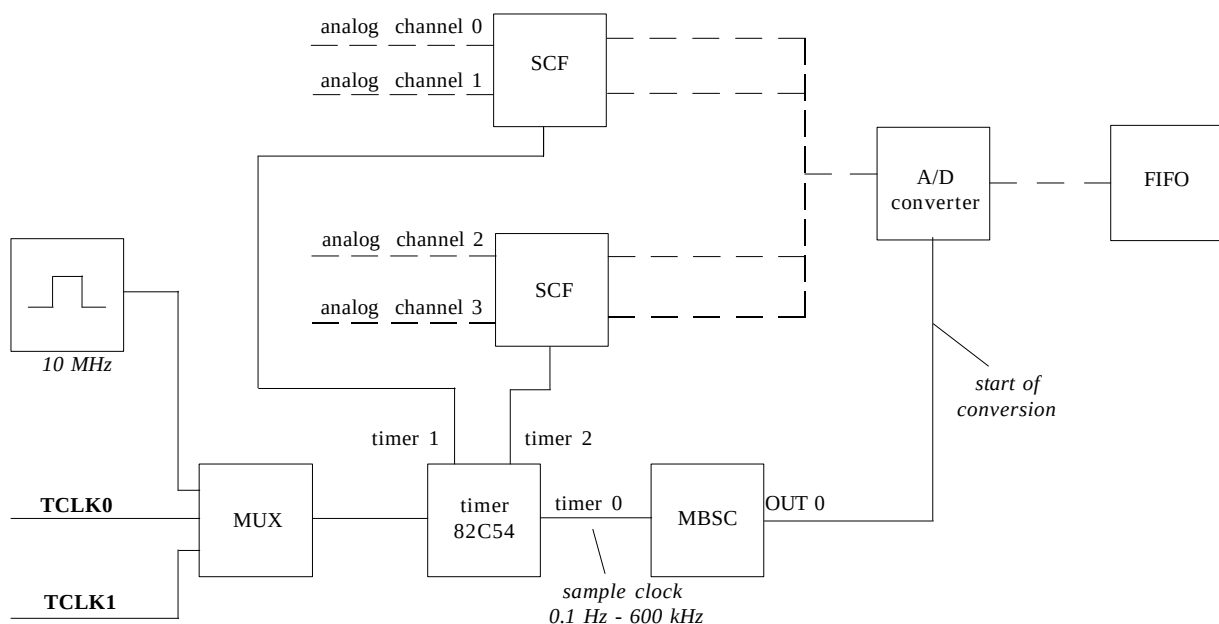
3.1 Master- and Slave Mode

The AD4-612 board can operate in the master- or slave mode. The difference depends on the handling of trigger signal **TRIG_I/O**. In the master mode, the trigger signal is generated by the AD4-612 board and can be used as input trigger signal for other boards (which are then operating in the slave mode). The trigger signal is switched to an output in the master mode and to an input in the slave mode. The programming can be performed in **control register 3** (address 16). If several boards are operating in parallel, only one board can operate as master and all other boards have to be configured as slaves. After reset, the AD4-612 board is in the slave mode. The AD4-612 board must remain in the slave mode if triggered by an external trigger master.

3.2 Clock Generation

The A/D converter requires a pulse called *Start Of Conversion*. With each *Start Of Conversion*, a value is sampled by the A/D converter and written into the FIFO. The *Start Of Conversion* pulse is generated by the MBSC. This requires a system clock called sample clock (*SMPLCLK*). The sample clock is generated by the Timer 0 of the timer module 82C54. The SCF low-pass filters of the analog inputs are also clocked by the timer module. In this case, timer 1 supplies the filters of analog channels 0 and 1, and timer 2 the filters of analog channels 2 and 3. The input clock of the timer module can be chosen from a multiplexer providing three options: It can either be a *10MHz* clock integrated on the AD4-612 board or one of the input ports **TCLK0** and **TCLK1** on the micro-line® bus. These input ports can be used when several AD4-612 boards are operating synchronously or when a very low *SMPLCLK* is used. The use of an external conversion might be necessary if a certain sampling rate is required which cannot be divided by 10MHz (e. g. 600 kHz by 10 MHz). The clock generation is supported by the supplied C-software drivers and should not be addressed directly by the application software.

Clock Generation Block Diagramm



3.3 The Display Function of the LEDs

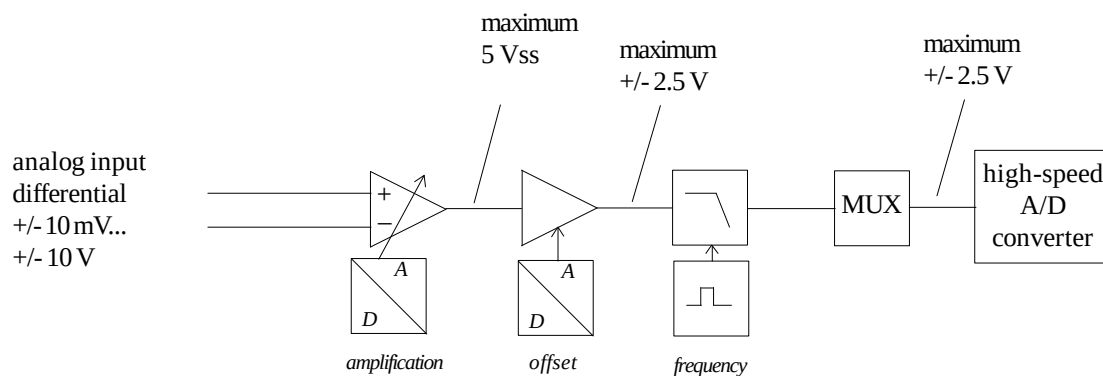
The AD4-612 board has a green and a red LED. The green LED turns on with the *Start Of Conversion* signal of the A/D converter, the red LED turns on with the FIFO full flag. During normal AD4-612 board operation, the green LED becomes brighter if the sample pause relation becomes more intense. In case of very low sampling rates ($<10\text{Hz}$), the light gradually changes to a low-frequency blinking what provides a good reception of the A/D converter activities.

The red LED light should not come on during normal AD4-612 board operation. The red LED shows a warning signal if a FIFO overflows. In this case, the processor is unable to take the pending data from the FIFO fast enough and a data loss occurs. If a FIFO overflow is recognized, the FIFO device has to be put into the basic state by a FIFO reset (control register 1, bit D3).

3.4 Analog Inputs

Each of the four analog inputs provides a programmable pre-amplifier, an offset amplifier and an anti-alias low-pass filter. The amplification and the offset can be pre-set by digital final control elements. The anti-alias low-pass filters are pre-set by programmable timers of the 82C54 module. The filters can be bypassed by several solder bridges on the AD4-612 board as the low-pass filters do not exceed the maximum corner frequency of 50kHz . Here, several solid Butterworth low-pass filters of 2nd order come into position. The corner frequencies (3dB attenuation) are then set to 100 or 200kHz for channel 1 and to 100kHz for channels 2 to 4. The MBSC automatically switches the analog multiplexer MUX.

Block diagram of the analog input channel:



3.5 A/D Converter Control

In order to receive a good A/D converter performance, the channels always need to be pre-set correctly. The A/D converter operates with an input voltage range of $\pm 2.5\text{V}$. This range should be achieved by tuning the pre-amplifier and the offset amplifier without overdriving the A/D converter.

For the analog inputs, a maximum voltage range of $\pm 10\text{V}$ and a minimum voltage range of $\pm 10\text{mV}$ is possible. Here, the input signal can have an offset range of $0..5\text{V}$ or $-10..0\text{V}$. After the correct setting, the output of the amplifier should have a maximum voltage level difference of 5Vss . This voltage level difference does not have to be zero-symmetrical. In order to achieve the required A/D converter zero-symmetry, the offset amplifier has to be programmed respectively.

The settings of the amplifier and the offset are supported by the supplied C-software drivers. Direct hardware accesses to the digital level recorder by the application software should be avoided.

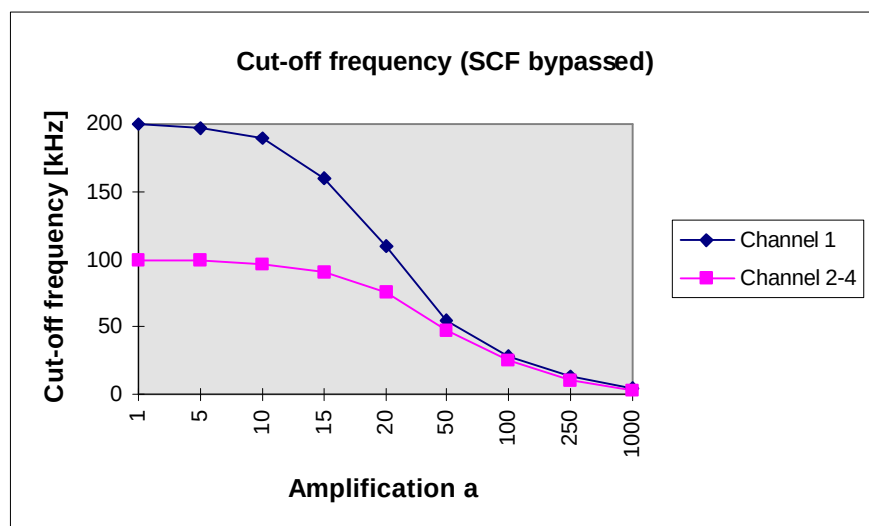
3.6 Programmable Amplification

The pre-amplifiers on the analog input can be programmed with a 12-bit resolution for each channel. These steps can optionally be configured to amplification or attenuation by closing the respective solder bridges on the AD4-612 board.

The amplification can be set by the software driver functions. Here, amplifications smaller than one are automatically converted to the correct A/D converter values of the amplification level.

The amplification additionally influences the upper corner frequency of the analog input channels due to general operational amplifier features. The upper corner frequency decreases depending on the tuned amplification. This can be realized at about ' $a = 10$ ' and has a tremendous effect when huge amplifications ($a = 100..1000$) apply. This effect does not apply if the amplifier is only used for attenuation.

Maximum cut-off frequency depending on the amplification:



3.7 Programmable Voltage Offsets

The voltage offsets of the analog inputs can be programmed with a 12-bit resolution for each channel. The voltage offsets can be directly provided in V to the software driver functions.

3.8 Examples for Programming Amplifications and Offsets for Maximum A/D Converter Control

Example 1:

input voltage	1Vss (zero-symmetrical, 0V Offset)
amplification:	2.5
voltage after the amplification level:	2.5Vss
offset:	0.3V (by component tolerance drives)
voltage of the A/D Converter:	2.5Vss (100 % drive)
amplifier DAC rate:	$4096 / 2.5 = 1638$
offset DAC rate:	$(0.3V + 3.75V) / 6.75V * 4096 = 2457$

Example 2:

input voltage:	0 to 1 V
amplification:	5
voltage after the amplification level:	0 to 5 V
offset:	2.6 V (2.5 V by input offset + 0.1 V (by component tolerance drives)
voltage of the A/D converter:	-2.5 to +2.5 V (100 % drive)

Example 3:

input voltage:	3 to 6 V
amplification:	0.64
voltage after the amplification level:	1.9 to 3.8 V
offset:	3.0 V (2.9 V by input offset + 0.1 V by component tolerance drives)
voltage of the A/D converter:	-1 to +1 V (only 40 % drive possible)

Example 4:

input voltage:	-5 V bis +1 V
amplification:	0,83
voltage after the amplification level:	-4.17 V bis +0.83 Vo
offset:	-1.57 V (-1.67 V by input offset + 0.1 V by component tolerance drives)
voltage of the A/D converter:	-2.5 bis +2.5 V (100 % drive)

3.9 Anti-Alias Low-Pass Filter

The input channels are equipped with Maxim SCF low-pass filters of 8th order. They show an attenuation of 48 dB / Octave. The used standard type MAX296 operates with Bessel characteristics, with the result of consistently good transient qualities despite the high attenuation. As an alternative, the AD4-612 board can be equipped with a MAX295 Butterworth characteristic filter type to further increase the operation frequency of the attenuation with the consequence of less favorable transient qualities and phase behavior (see data sheets in the appendix).

The filters are clocked with the timer module 82C54. Here, timer 1 supplies the filters of analog channels 0 and 1 and timer 2 the filters of analog channels 2 and 3. The corner frequencies (3dB attenuation) of the filters are 1/50 of the input clocks.

The settings of the corner frequencies are supported by the supplied C-software drivers. Direct hardware accesses from the application software are not allowed.

The programmable SCF filters are followed by fixed low-pass filters of 2nd order (-12 dB / Octave, Butterworth characteristic) in order to attenuate clock emissions of the SCF filters. The SCF filters can furthermore be totally de-activated (by-passed) by several solder bridges on the AD4-612 board to support the input signals > 50kHz. In this case, only the fixed low-pass filters are used. The frequencies of the filters following are 200kHz or 100kHz (each solder bridge can set separately) for channel 1 and 100 kHz for channels 2 to 4. The frequency information always shows the -3 dB attenuation. After changing the solder bridges, another zero-balancing of the AD4-612 board should be made as the offset rates of the input channels could have changed.

If the SCF filter of channel 1 is operated with corner frequencies < 8 kHz, the solder bridges of the following low-pass filter should be set to 100 kHz (=basic state after the delivery state) in order to effectively attenuate possible SCF clock feedthrough. This is especially the case when the A/D converter is tuned to a low rate.

If the SCF filters operate with corner frequencies < 4 kHz, a light digital post-filtering via software can be considered because the post-connected low-pass filters with a corner frequency of 100 kHz become invalid when small SCF corner-frequencies are used. This helps avoiding SCF clock-feedthrough. This effect will be even stronger if the set SCF corner frequency and the A/D converter drive become smaller.

3.10 Multiplexer

The multiplexer is automatically controlled by the MBSC. Here, the multiplexer channels 0 to 3 are switched to the analog inputs 1 to 4. For testing and comparisons, channel 4 is switched to ground voltage + 1.25 V, channel 5 to + 2.5 V and channel 6 and 7 to ground.

Classification of the multiplexer inputs:

multiplexer channel	input
0	analog input 1
1	analog input 2
2	analog input 3
3	analog input 4
4	reference voltage + 1.25 V
5	reference voltage + 2.5 V
6	0 V
7	0 V

3.11 E²PROM

The AD4-612 board has an integrated serial E²PROM, type 24C02, with an I²C bus interface to permanently store adjustments of the operating parameters. With the zero-balancing, the offset and amplification (delivery state: amplification = 1, offset = 0) can be stored to the permanent memory. During reset, the adjustment parameters can be read from the E²PROM and do not have to be balanced to zero again. The ports of the I²C bus interface are addressed via the *control register 2* (address 12). They are: **I2C_SCL** (serial clock) and **I2C_SDA** (serial data). Die I²C bus ports lead to the outside in order to enable external expansions.

All E²PROM module accesses are supported by the supplied C-software drivers. Direct hardware accesses from the application software are not allowed.

The E²PROM technology does not allow an unlimited number of write accesses, therefore too many write accesses to the E²PROM module should be avoided. The used module is specified for a maximum of 100,000.00 write accesses, otherwise the module could be destroyed. This limitation only applies to write accesses and not to read accesses.

4. Register Description

4.1 Timer

The timers of the MBSC are supported by the supplied C-software drivers and should not be directly accessed via the application software. The description of the respective software drivers can be found on pages 18 ff.

4.2 Registers

The initializing parameters necessary for the AD4-612 board operation have to be entered into the respective registers via software. The base address of the AD4-612 board is determined by one of the chip-select input signals **/CS1 bis /CS7** of the micro-line® bus. The **/CSx** signal is produced by the connected processor module and can be chosen by placing the respective solder bridge on the AD4-612 board. The additional address ports **A0 to A5** are used for a further decoding of the AD4-612 board's single registers.

Register description:

base address offset	name	read / write
0...3	82C54 clock generator (data sheet 82C54)	read and write
4	parallel port	write only
4	FIFO read register	read only
8	FIFO status register	read only
8	control register 1	write only
12	control register 2	read and write
16	control register 3	write only
20	number of channels	write only
24	number of idle positions (bit 3..0)	write only
28	number of idle positions (bit 7..4)	write only
32	number of sampling rates per channel (bit 3..0)	write only
36	number of sampling rates per channel (bit 7..4)	write only
40	number of sampling rates per channel (bit 10..8)	write only
44	length of the pause (bit 3..0)	write only
48	length of the pause (bit 7..4)	write only
52	length of the pause (bit 10..8)	write only

4.2.3 FIFO Status Register

address: offset 8

read only

D31

D2 D1 D0

x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	--	--	--

x = not used

The flags of the FIFOs can be read by the FIFO status register.

- D0 FIFO empty flag 0 if FIFO is empty, 1 if FIFO is not empty.
- D1 FIFO half full flag 0 if FIFO is more than half full, 1 if FIFO is less than half full.
- D2 FIFO full flag 0 if FIFO is full, 1 if FIFO is almost full.

4.2.4 Control Register 1

address: offset 8

write only

D31

D3 D2 D1 D0

x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	--	--	--	--

x = not used

- D0 INTENA-EF interrupt enable FIFO not empty. The interrupt becomes active if the FIFO is not empty. 1 means that the interrupt is activated, 0 turns the interrupt off. The active interrupt port can be switched via a respectively configured solder bridge from /INT0 to /INT3.
- D1 INTENA-HF interrupt enable FIFO half full. The interrupt becomes active if the FIFO is at least half full. 1 means that the interrupt is activated, 0 turns the interrupt off. The active interrupt port can be switched via a respectively configured solder bridge from /INT0 to /INT3.
- D3 FIFO-RESET FIFO reset. The reset for the FIFO starts if a 1 is written into this register. The write triggers a short reset impulse. A write of a 0 has no effects.

5. Software:

The AD4-612 software includes functions to initialize the board components to measure or permanently store the parameters. The software supports all board components and should mandatorily be used for hardware control. Direct hardware accesses from the application software are not allowed.

The necessary functions to control the AD4-612 board are combined in a library. Translated versions provided for the Texas Instruments DSPs C3x, C44 and C203 can be found in the respective sub-directory of the installation disc. For the micro-line® boards C203CPU, C31CPU, C32CPU, and C44CPU translated example programs can be found in the sub-index '**example**'. The example programs in the sub-directory '**example**' have to be connected with a terminal incl. the following parameters: 19200 baud, 8 data bits, 1 stop bit, no parity, no handshake, line skip LF (ASCII 0x0D).

The libraries for the floating-point DSP board are translated for the small-memory model with the stack-parameter delivery. Libraries with other operation models can be created with the help of the mk30.exe program; the respective sources can be found in the **source** directory of the AD4_612.src library. The application of the mk30.exe program is described in paragraph 6 of the TMS320 floating-point DSP optimizing C-compiler user's guide.

The TMS320C203 library version requires the functions of the **io_port.obj** file. Therefore, the file has to be entered into the linker-command file and then be copied to where it can be found by the linker (e. g. the project directory).

The function prototypes and declarations of the global variable can be found in the include file **ad4_612.h**.

5.1 Global Variable:

```
int      EEPROMError;      (eprom.c in ad4_612.src)
```

The variable EEPROMError is set to 1 if the access to the E²PROM of the AD4-612 board runs into a time-out.

```
double   Offset[8];        (operat.c in ad4_612.src)
double   Gain[8];          (operat.c in ad4_612.src)
long      CutOffFreq[8];    (operat.c in ad4_612.src)
```

These three vectors reflect the offset values, the amplifications, and corner frequencies of the AD4-612 board's single channels. The values stored in the vector have to be activated if the respective parameters of a channel are changed.

```
struct AD_4_612_STRUCT ad4_612;    (operat.c in ad4_612.src)
```

This structure includes the AD4-612 board's operation parameter. It is not allowed to directly manipulate the included values.

5.2 Functions:

5.2.1 Initialisation (operat.c in ad4_612.src)

```
int      OperationMode(int NrOfChannels,
                        int NrOfSamples,
                        int PauseLength,
                        int Mode,
                        int InterruptMode,
                        long SourceFreq,
                        long SampleFreq,
                        int IOBaseAddr);
```

The operation mode is for the basic setting of the AD4-612 boards. The settings are not stored permanently.

NrOfChannels: The number of channels to be read.
NrOfSamples : The number of samples in a burst of the Single Shot Burst Mode.
PauseLength : The pause between two burst packets in the Repeat Burst Mode.
Mode : Master, slave and single shot operation of the AD4-612 board. Here, the in the AD4_612 A'file defined constants 'SLAVE MODE', 'MASTER MODE' und 'SINGLE SHOT' apply. In order to activate the single shot operation, the constant 'SINGLE SHOT' has to be connected with the 'MASTER MODE' or 'SLAVE MODE' constants. Performing an OR operation of the constant 'SS' and either 'MM' or 'SM' activates the single shot operation.
InterruptMode: Determines whether the half full flag or the empty flag of the FIFO triggers an interrupt. Here, the in the 'AD4_612.h' file defined constants 'INTENA_EF' or 'INTENA_HF' apply.
SourceFreq : The clock frequency of the 82C54 timer. The value corresponding with the frequency of the chosen clock source by the SourceClk().
SampleFreq : The sampling rate of the AD4-612 board.
IOBaseAddr : The base address of the AD4-612 board.

OperationMode returns a 1 if an error occurred, otherwise 0.

An example for the interrelation of the channel number, number of bursts, pause length and sampling rate is provided in paragraph 9.

```
void      SourceClk(int Mux);
```

The SourceClk() chooses the clock source for the 82C54 timer. There is a choice between the internal 10MHz clock or the two external clock inputs TCLK0 or TCLK1 of the micro-line® bus. The corresponding constants are defined in the 'AD4_612.h' file.

```
void      Start(void);
```

Start() starts the AD4-612 board with the parameters set earlier. In the Single Shot Mode, the sampling has to be re-started after each burst by the command start().

void FIFOReset(void);

FIFOReset() sets back the FIFO of the AD4-612 board.

void Reset(void);

Reset() sets the amplification of all channels to one and sets an offset rate of zero.

double SampleClk(double SampleFreqPerChannel);

SampleClk() sets the number of samples per second, which have to be read for each channel. SampleClk() uses the functions SetConvClk() and SetIdle(). The function SampleClock() should not be called up directly, instead all settings regarding the timing and data conversion should be carried out by the function OperationMode().

long SetConvClock(double ConvFreq);

SetConvClock() sets the sampling rate of the A/D converter, i. e., the distance between the two values of a sample. This value influences the phase relation between the sampling rates of the different channels as well as the 82C54 timer frequency. The set frequency is valid for all activated input channels. The return value is corresponding to the relation between the frequency of the chosen conversion source by the SourceClk() and the call-up parameter ConvFreq. It is not allowed to directly call up the function SetConvClock(). Instead, all settings regarding the timing of the data conversion should be carried out by the OperationMode() function.

void SetIdle(int Idle);

SetIdle sets the number of idle cycles between two sample packets of the A/D converter. The delivered value is corresponding with the number of read channels minus one plus the number of idle cycles. The length of an idle cycle is determined by the set sampling rate of the SetConvClock() function. It is not allowed to directly call up the function SetIdle(). Instead, all settings regarding the timing of the data conversion should be carried out by the function OperationMode().

5.2.2 Adjusting and Storing of Parameters (params.c in ad4_612.src)

The following functions set the AD4-612 board's operation parameters. When using the functions to memorize parameters in the AD4-612 board's E²PROM, it is important to know that the E²PROM technology allows only a limited number of write cycles. The used module is specified with at least 100,000 write cycles. Therefore, unnecessary write accesses have to be avoided.

void RecallAll(void);

RecallAll() reads all amplification, offset and corner frequency values for all channels from the E²PROM of

the AD4-612 board. The values for the maximum sampling frequency and the SCF clock frequency are initialized. RecallAll() reads the E²PROM only if the version of the parameter sentence called up by the 'RecallVersion()', corresponds with the constant 'STD_directly VERSION' in the 'ad4_612.h' data sheet. Otherwise, the offset values are set to zero, the amplification values are set to one and the corner frequencies to 20 kHz.

```
double    SetGain(int channel, double value);
```

SetGain() sets the amplification of the A/D converter channel. The values of 'Value' range from 0 to 4096. Depending on the setting of the solder bridges on the AD4-612 board, there is either an amplification or attenuation of the input signal. The return value includes the actually set amplification factor, i. e. the amplification factor without rounding errors or errors from overranging.

```
double    SetGaindB(int channel, double value);
```

SetGaindB() sets the amplification of the A/D converter channel. The amplification value is stated in dB. The return value is corresponding with the actually set amplification dB.

```
double    SetOffset(int channel, double value);
```

SetOffset() sets the offset of a stated channel. The offset voltage is stated in volts with valid values between -3.75 V and + 3 V. The return value is corresponding with the actually set offset, i. e. without rounding errors and errors from overranging.

```
double    SetCutOffFreq(int channel, double value);
```

SetCutOffFreq determines the corner frequency of the AD4-612 board's input filter. The minimum corner frequency is 0.1 Hz, the maximum frequency is 50 kHz. The setting is always valid for a pair of channels, i. e. channel 1 and 2 as well as channel 3 and 4 have the same corner frequency. The return value is corresponding with the actually set corner frequency.

```
double    SaveGain(int channel, double value);
```

SaveGain() permanently stores the delivered amplification value of 'Value' in the E²PROM of the AD4-612 board. The return value is corresponding with the actually stored amplification factor.

```
double    SaveOffset(int channel, double value);
```

SaveOffset() permanently stores 'Value' as offset of the stated channel in the E²PROM of the AD4-612 board. The return value is corresponding with the actually stored offset rate.

```
double    SaveCutOffFreq(int channel, double value);
```

SaveCutOffFreq() permanently stores the corner frequency of the input filter for a channel pair in the

E²PROM of the AD4-612 board. The return value is corresponding with the actually stored corner frequency.

```
double    RecallGain(int Channel);
```

RecallGain() reads the amplification value of the stated channel from the E²PROM of the AD4-612 board.

```
double    RecallOffset(intChannel);
```

RecallOffset() reads the offset value of the stated channel from the E²PROM of the AD4-612 board.

```
double    RecallCutOffFreq(int Channel);
```

RecallCutOffFreq() reads the corner frequency of a channel from the E²PROM of the AD4-612 board.

```
long      RecallVersion(void);
```

RecallVersion() reads the version of the parameter set included in the E²PROM of the AD4-612 board.

```
long      SaveVersion(long version);
```

SaveVersion() stores the delivered version number of the parameter set included in the E²PROM of the AD4-612 board. The version number is cut to a length of 16 bits.

```
int       SaveSCFRatio(int Ratio);
```

SaveSCFRatio permanently stores the valid relation between the clock frequency and the corner frequency of the filter module in the AD4-612 board's E²PROM . The setting is carried out by the manufacturer during the first operation and should not be changed.

The valid range is between 50 and 100. The return value is corresponding with the actually stored ratio.

```
int       RecallSCFRatio(void);
```

RecallSCFRatio reads the valid relation for the used filter module between the clock frequency and corner frequency from the E²PROM of the AD4-612 board.

```
long      SaveMaxConvFreq( long Rate );
```

SaveMaxConvFreq() permanently stores the AD4-612 board's valid maximum sampling rate in Hz of the A/D converter in the E²PROM. This setting is carried out by the manufacturer during the first operation and should not be changed. The valid range is between 500kHz and 600kHz. The return value is corresponding with the actually stored maximum frequency.

```
long      RecallMaxConvFreq(void);
```

RecallMaxConvFreq() reads the AD4-612 board's maximum valid sampling rate in Hz from the E²PROM of the AD4-612 board. The maximum valid sampling rate is used for the A/D converter.

5.2.3 Calibration (calib.c in ad4_612.src)

The functions in calib.c balance the offsets of the AD4-612 board's input amplifiers. AdCalib() adjusts the offsets without permanently storing the received values. CalibAndSave() permanently puts the received offset values to the E²PROM of the AD4-612 board. It is important to know that the E²PROM technology does not allow an unlimited number of write accesses. The used module allows a maximum of 100,000 write accesses. Therefore, unnecessary write accesses should be avoided.

```
double    AdCalib(long SampleCount, int NrOfChan, double Limit);
```

AdCalib() balances the offset voltage of the AD4-612 board's input amplifiers to zero volt. Here, a 'SampleCount' about the values is made for each channel. 'NrOfChan' has to correspond with the adjusted number of channels in the OperationMode(). The calibration ends if the offset for all channels is smaller than 'Limit'. The 'Limit' value is stated in V (1 LSB of the A/D converter corresponds to 1.2mV). The largest offset value of all channels will be returned. The calibration should only be done with open (without an Input Signal) or short-circuit analog inputs. AdCalib() uses the stored values of the global variables 'Gain[]', 'Offset[]' and 'CutOffFreq[]'. The results of the calibration are stored in 'Offset[]'. In order to balance a certain amplification and corner frequency, the global Variables 'Gain[]' and 'CutOffFreq[]' are set to the requested value for each channel and called up by the AdCalib().

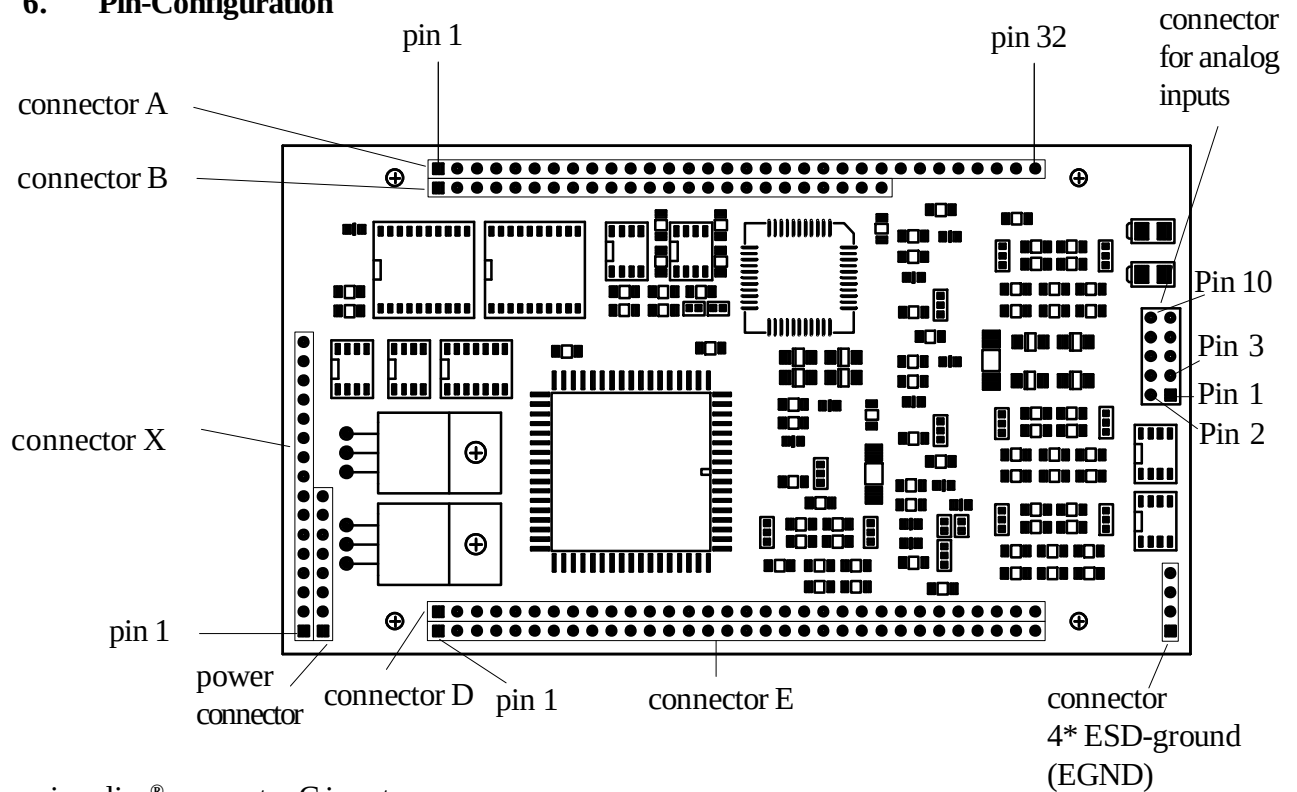
```
void      CalibAndSave(long SampleCount, int NrOfChan, double Limit);
```

CalibAndSave() balances the offsets of all channels and permanently stores the values with the OfflineBoardCalibration() functions in the E²PROM of the AD4-612 board. Here, CalibAndSave() uses the global variables 'Offset[]', 'Gain[]' and 'CutOffFreq[]'. The call-up parameters are the same as for the AdCalib() function. CalibAndSave() is used to determine the operation parameters of the AD4-612 board for a certain application.

```
void      OfflineBoardCalibration(int Channel, double *Gain, double *Offset,  
                                  long *CutOffFreq);
```

OfflineBoardCalibration() permanently stores the values 'Gain', 'Offset' and 'CutOffFreq' as parameters of the channels which are specified 'Channel' in the E²PROM of the AD4-612 board. The delivery parameters for amplification, offset and corner frequencies actually return stored values.

6. Pin-Configuration



micro-line® connector C is not occupied

Pin	connector A	connector B	connector D	connector E	connector X	input	power
1	D00(I/O)	A00(I)	DGND(I)	-	TRIG_I/O(I/O/Z)	AIN1+	A +15 V
2	D01(I/O)	A01(I)	DGND(I)	-	-	AIN1-	AGND
3	D02(I/O)	A02(I)	DGND(I)	-	-	AIN2+	AGND
4	D03(I/O)	A03(I)	DGND(I)	-	-	AIN2-	A -15 V
5	D04(I/O)	A04(I)	D+5 V(I)	-	-	AIN3+	-
6	D05(I/O)	A05(I)	D+5 V(I)	-	-	AIN3-	X +7 V
7	D06(I/O)	-	-	-	-	AIN4+	XGND
8	D07(I/O)	-	/RESET(I)	-	-	AIN4-	-
9	D08(I/O)	-	-	-	-	EGND	
10	D09(I/O)	-	/CS1(I)	-	-	EGND	
11	D10(I/O)	-	/CS2(I)	-	-		
12	D11(I/O)	-	/CS3(I)	-	-		
13	D12(I/O)	-	/CS4(I)	-	-		
14	D13(I/O)	-	/CS5(I)	-	-		
15	D14(I/O)	-	/CS6(I)	-	I2C_SCL(OC)		
16	D15(I/O)	-	/CS7(I)	-	I2C_SDA(OC)		
17	-	-	/INT0(OC)	-			
18	-	-	/INT1(OC)	-			
19	-	-	/INT2(OC)	-			
20	-	-	/INT3(OC)	-			
21	-	-	-	-			
22	-	-	-	-			
23	-	-	-	-			
24	-	-	R/W(I)	-			
25	-		/STRB(I)	-			
26	-		-	-			
27	-		-	-			
28	-		-	TCLK0(I)			
29	-		-	TCLK1(I)			
30	-		-	-			
31	-		-	-			
32	-		-	-			

6.1 Pin-Discription

The pin-discription corresponds to micro-line® standard and is compatible with all micro-line® processor- and peripheral boards. Several peripheral boards can be used as piggy-pack units and be operated with a processor board when they are plugged onto each other.

Connector A:

D00...D15:

These are the bi-directional data lines of the mirco-line® bus. They are permanently configured as inputs and are only briefly switched to outputs for external read cycles.

Connector B:

A00...A05:

These are the address lines of the micro-line® bus. They are permanently switched to inputs.

Connector D:

DGND:

Power supply: digital ground

D+5 V:

Digital power supply: +5V. All digital modules are power-supplied via this connector. The maximum valid voltage is +5.5V.

/RESET:

Reset input (active low) for an externally triggered master reset.

/CS1.../CS7:

Chip select inputs (active low). One of the /CSx signals has to be activated in order to enable the processor board to access the AD4-612 board. Solder bridges select one of the seven chip select signals directed to the entire system configuration on the micro-line® bus. It is important that two or several peripheral boards must not be operated with the same chip select signals but be configured differently which means that they are accessible by different I/O addresses of the processor board.

/INT0.../INT3:

Interrupt outputs (active low, open collector). One of the four interrupt outputs /INTn can be activated by a solder bridge in order to signal an interrupt to the processor board. If several peripheral boards are operated on the micro-line® bus, each board should be configured to a separate interrupt signal. If this is not possible, several hardware interrupt-lines can be connected together because of the open collector feature. The interrupt service routine then has to recognize the active interrupt source by respective polling.

R/W:

The AD4-612 board's read/write input signals. In the 'high' state, a read access and in the 'low' state, a write cycle is signaled.

/STRB:

The AD4-612 board's strobe input signal (active low) signals an external read or write access.

Connector E:**TCLK0,TCLK1:**

Timer clock input signals. Instead of the internal 10 MHz oscillator, the clocks can be configured as system time base.

Connector X:

The eXpander connector is for expansions of the micro-line® bus and exclusively reserved for peripheral systems.

TRIG_I/O:

Trigger signal (active high) for the Multi Burst Sample Controller (MBSC). If the AD4-612 board operates in the slave mode, the pin is switched to input and if the AD4-612 board operates in the master mode, the pin is switched to output.

The impulse length for the trigger signal should be a clock cycle of the *SmplClk*. The impulse length must not be larger than the length of a sample because multiple triggering could be started.

I2C_SCL

The I²C-bus serial clock is an open collector signal with integrated pull-up resistor.

I2C_SDA

The I²C-bus serial data is an open collector signal with integrated pull-up resistor.

Analog Input Connectors:**AIN1+ AIN1-****AIN2+ AIN2-****AIN3+ AIN3-****AIN4+ AIN4-**

They are the analog inputs of channels 1 to 4. The input resistance is 20 kOhm. They are differential inputs with the signals AIN1 to AIN4 with + and - signals available. If the signal source has only one ground-related (not a differential) analog signal available, the ground of the signal provider should be transmitted by the cable signal together with the user signal as - level and be connected with the -input of the AD4-612 board. If possible, no direct mass connection between the signal provider and the AD4-612 board should be made. This method reduces possible voltage noises.

The voltages of the + pins should, in opposite to the -pins, not exceed the maximum rate of +/-11 V.

Regarding the **EGND** pins, the +/- 15 V rate should not be exceeded because the integrated protection diodes can short-circuit the analog inputs.

EGND Plug

ESD ground (Electro Static Discharge). There are four **EGND** pins on this additional plug. With these ground signals, possible overloads can be conducted from the analog inputs. The pins should possibly be connected with the case ground and the protection ground. If they are not available, a connection to the analog ground (power plug pin 2 and 3) is recommended. Here, the analog inputs are only protected from excessive signal levels and not from electrostatic discharges. On the analog input plug, the two EGND pins can be used to shield the analog input cable.

Power Plug

There is a separate power plug for the power supply of the analog board components. Here, only 'pure' and potential-free voltages should be supplied. The voltage should be generated externally, e. g., via a high-quality DC/DC converter from a digital +5 V voltage. Each impure voltage directly affects the quality of the A/D conversion. The quality of the analog power supplies is measured on the noise- and potential-free voltages and not on the complete voltage value (because all analog voltages on the AD4-612 board are double-stabilized with linear regulators). All voltages should always be started at the same time (incl. D+5V). The AD4-612 board could be destroyed if it is not fully supplied (in case of divided voltages).

A +15 V

Analog positive voltage supply. The valid voltage range is +14 V to +16 V.

A -15 V

Analog negative voltage supply. The valid voltage range is -14 V to -16 V.

AGND

Analog ground. High-quality ground.

X +7 V

Analog positive voltage supply of the A/D converter. The valid voltage range is +7 V to +16 V. The power supply X +7 V can be tapped from power supply A +15 V which means it does not necessarily have to be potential-free from the analog power supply.

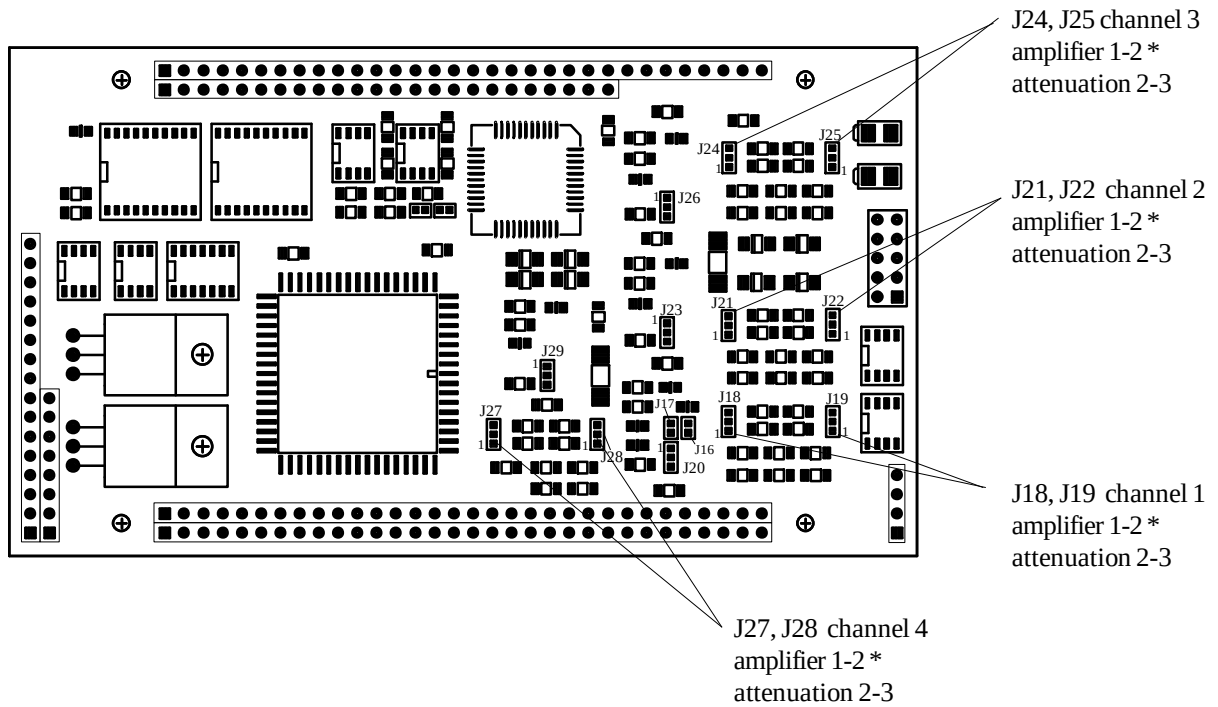
XGND

Analog ground of the A/D converter. High-quality ground. XGND can be tapped from the AGND which means it does not necessarily have to be potential-free from the analog power supply.

7. Solder Bridges

7.1 Input Amplification / Input Attenuation

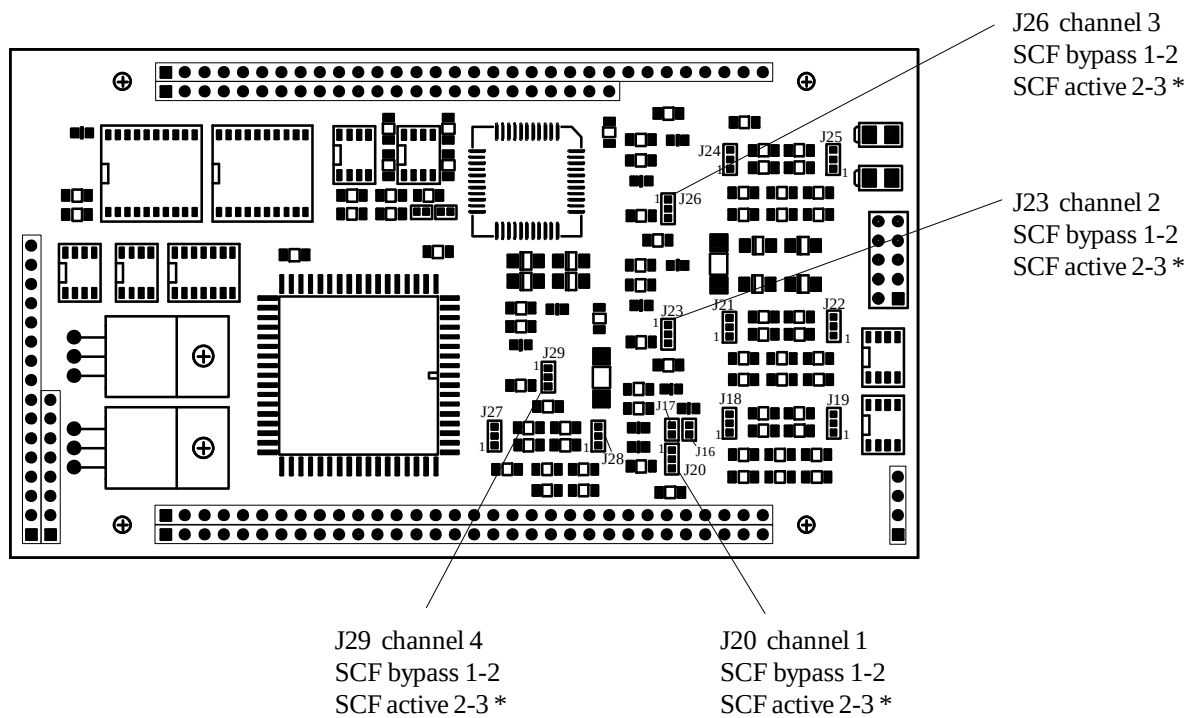
With the help of several solder bridges, the characteristics of the AD4-612 board's input amplifiers can be separately set for all four channels. Through the respective configuration, either an amplification ($1 < v < 4095$) or an attenuation ($0 < v < 1$) can be set. For amplification, pin 1 and 2 and for attenuation, pin 2 and 3 have to be connected with each other. For each channel, two solder bridges have to be configured simultaneously.



** In the delivery state, pins 1 and 2 are connected (amplification is set).*

7.2 SCF Filter Activation / De-Activation

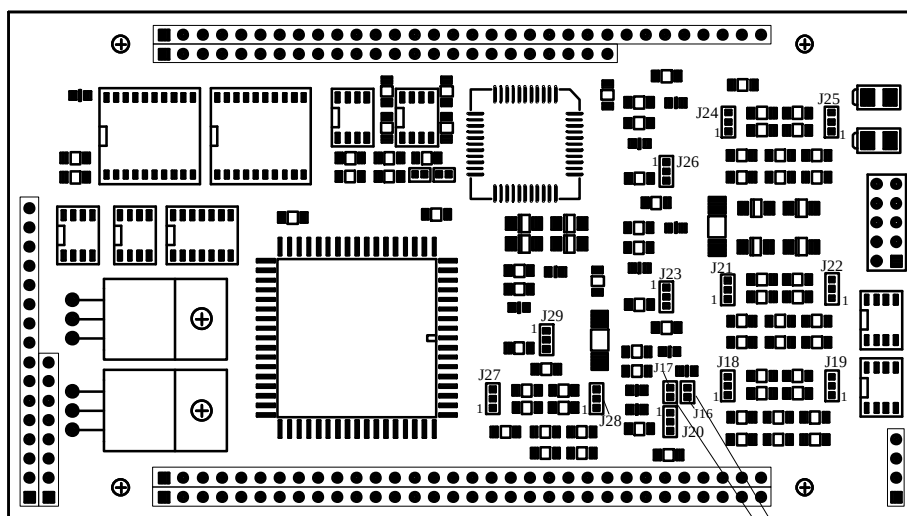
In order to activate or de-activate (bypass) the SCF filters, one solder bridge has to be configured for each analog channel. In order to activate the SCF filters (delivery state), pins 2 and 3 each have to be connected with the respective solder bridges. In order to de-activate the SCF-filters, pins 1 and 2 have to be connected with the respective solder bridges.



* In the delivery state, pins 2 and 3 are connected (SCF filter is active).

7.3 Channel 1 Corner Frequency (100kHz or 200kHz)

The corner frequency of the post-connected, fixed low-pass SCF filter on analog channel 1 can optionally be set to 100 kHz or 200 kHz. Here, two solder bridges have to be configured. If J16 and J17 are closed, a corner frequency of 100kHz is set (delivery state). If both solder bridges are open, the low-pass filter is set to 200kHz. Both solder bridges always have to be either open or closed at the same time.

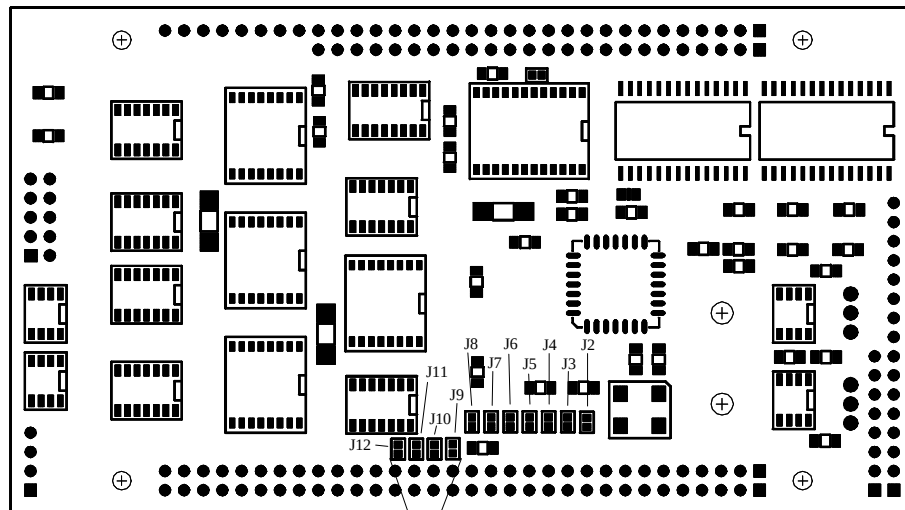


J16, J17
low-pass filter channel 1
closed = 100kHz *
open = 200kHz

** In the delivery state, J16 and J17 are closed (they are tuned to 100kHz).*

7.4 Interrupt Pins /INT0 to /INT3

Due to the AD4-612 board's functionality, an interrupt signal can be triggered to a plugged-on processor module. Here, the used interrupt port (/INT0, /INT1, /INT2 or /INT3) has to be set for each solder bridge. A closed solder bridge activates the respective interrupt. All other interrupt solder bridges must remain open. In the delivery state, solder bridge J9 is closed which means that **INT0** is active.

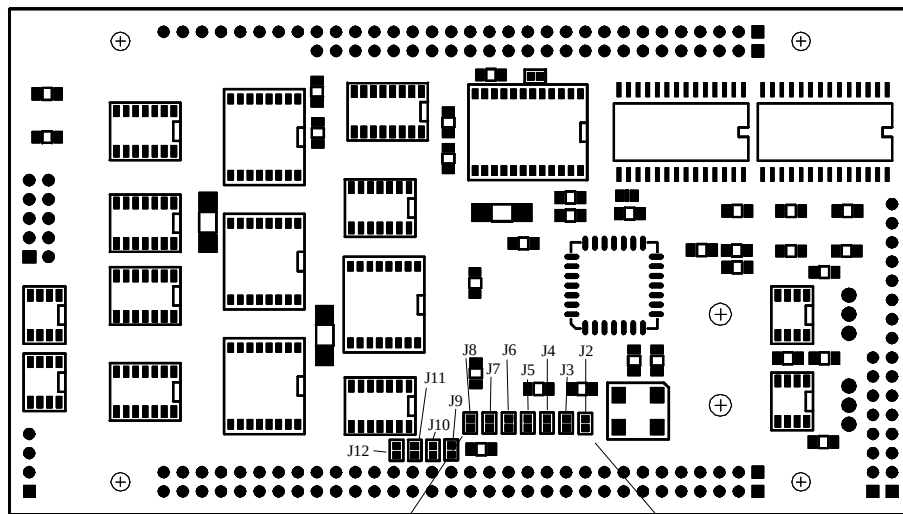


place J9 = interrupt 0 (/INT0) active
place J10 = interrupt 1 (/INT1) active
place J11 = interrupt 2 (/INT2) active
place J12 = interrupt 3 (/INT3) active

** In the delivery state, J9 is closed meaning (/INT0 is activated).*

7.5 Chip Select Signals /CS1 to /CS7

Every peripheral board on the micro-line® bus has a separate chip select signal. Therefore, it can be addressed by the processor module on an own I/O address. Here, one chip select signal must be selected from altogether 7 possible chip select signals. The selection takes place on the AD4-612 board by configuring solder bridges J2 to J8 . A closed solder bridge activates a chip-select signal. All other chip select signals must remain de-activated which means that their solder bridges are open. In the delivery state, solder bridge J 2 is closed which means it is **/CS1** active.

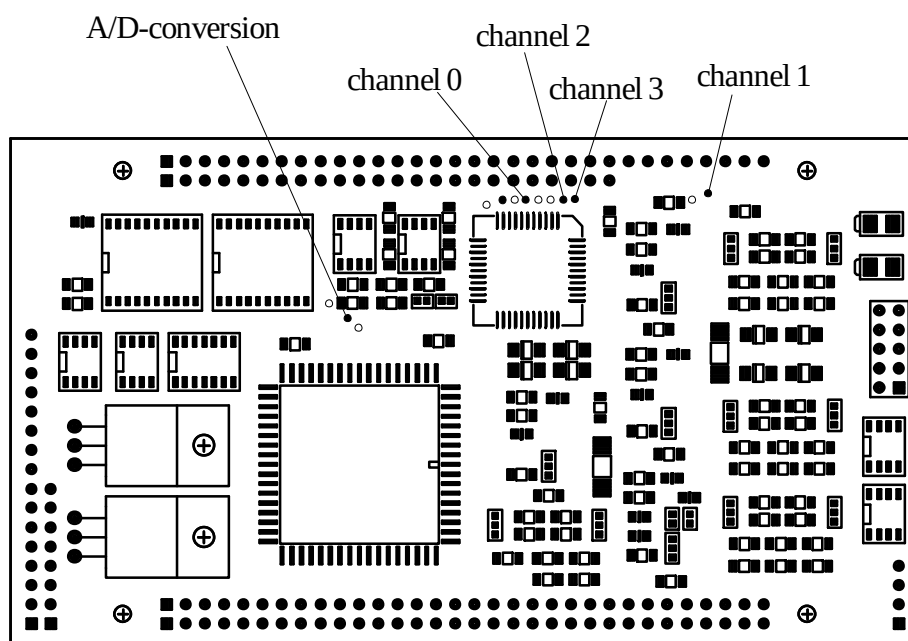


place J2 = chip select 1 (/CS1) active
place J3 = chip select 2 (/CS2) active
place J4 = chip select 3 (/CS3) active
place J5 = chip select 4 (/CS4) active
place J6 = chip select 5 (/CS5) active
place J7 = chip select 6 (/CS6) active
place J8 = chip select 7 (/CS7) active

** In the delivery state, J2 is closed (/CS1 is activated).*

8. Test Measuring Access Points

The signals of the AD4-612 board's four analog channels can be measured as shown below. The test measuring access points are located behind the programmable amplifiers and behind the offset contact element and are respectively corresponding with the signals for the A/D converter. There is a further test measuring access point for the A/D conversion. The test measuring access points can be distinguished by the pewtered contacts.



9. Example for MBSC Programming

The following is to exemplify the programming of the MBSC with the help of the driver function `OperationMode()`. Here, the calling parameters are used which were also translated with the example program on the disc.

```
int      OperationMode(int NrOfChannels,    = 8
                        int NrOfSamples,    = 2
                        int PauseLength,    = 4
                        int Mode,           = MASTERMODE
                        int InterruptMode,  = 0
                        long SourceFreq,    = 10MHz
                        long SampleFreq,   = 10kHz, equivalent to 100µs
                        int IOBaseAddr);    = I_O_PORT1
```

The parameter `IOBaseAddress` depends on the configuration of the total systems. The solder bridges to determine the base address of the AD4-612 board are described in paragraph 7.5.

`SampleFreq` determines the distance of two samples which is consisting of a sampling value for each channel and is stated in Hertz.

The parameter `SourceFreq` specifies the frequency of the clock source of the AD4-612 board. Besides the 10MHz oscillator on the AD4-612 board, an external signal can be supplied with the ports `TCLK0` and `TCLK1` of any frequency. The selection of the clock source is carried out with function `SourceClk()`. The frequency is stated in Hertz.

The `InterruptMode` determines whether and when the AD4-612 board generates an interrupt. This applies if the FIFO of the AD4-612 board is not empty or more than half full. There are no interrupts used in the example. The header file `AD4_612.H` defines constants for interrupt masking, an example for an Interrupt Service Routine can be found in file `ADTEST.C`.

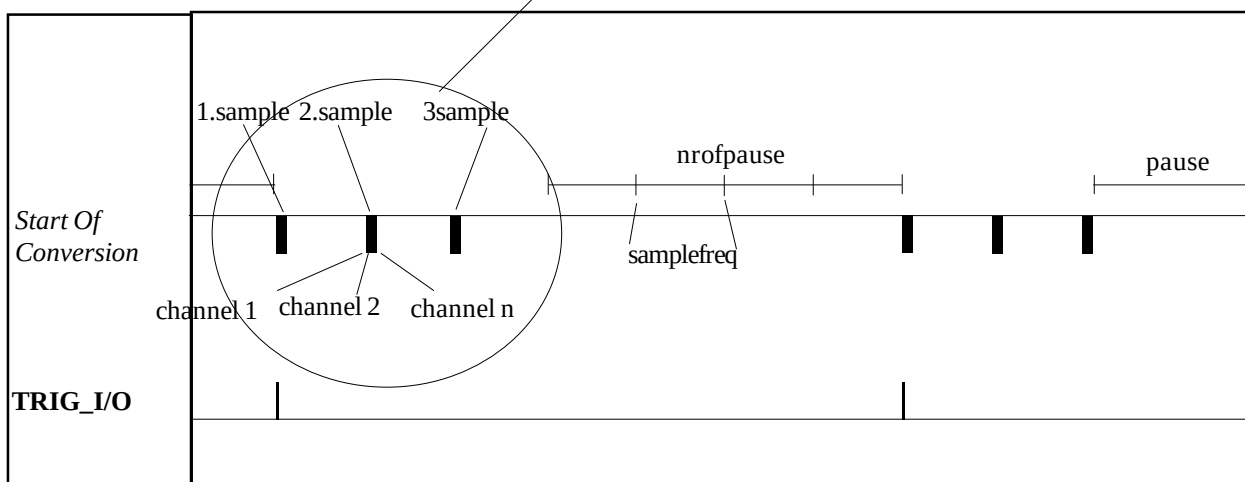
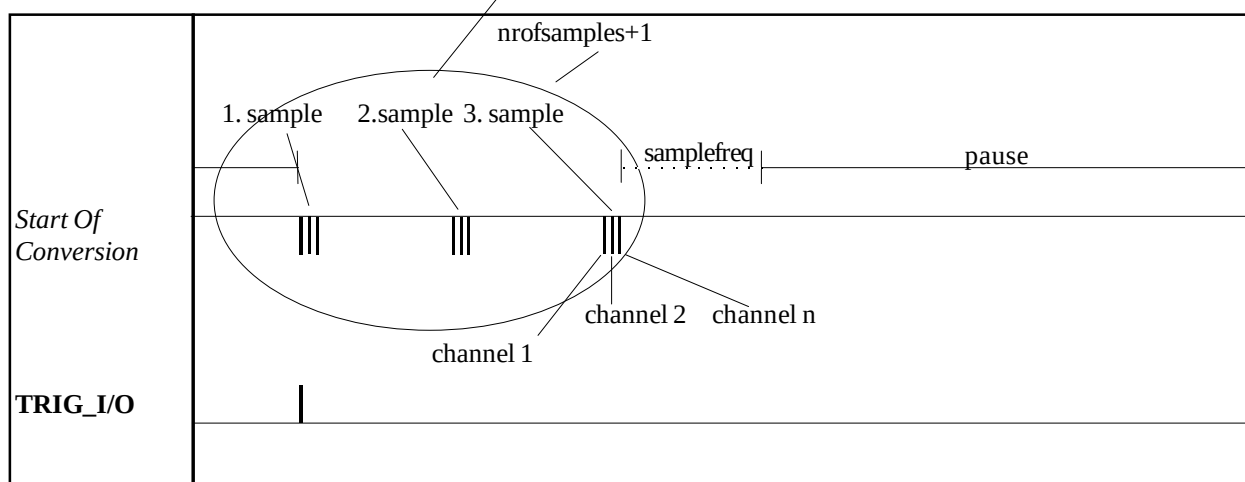
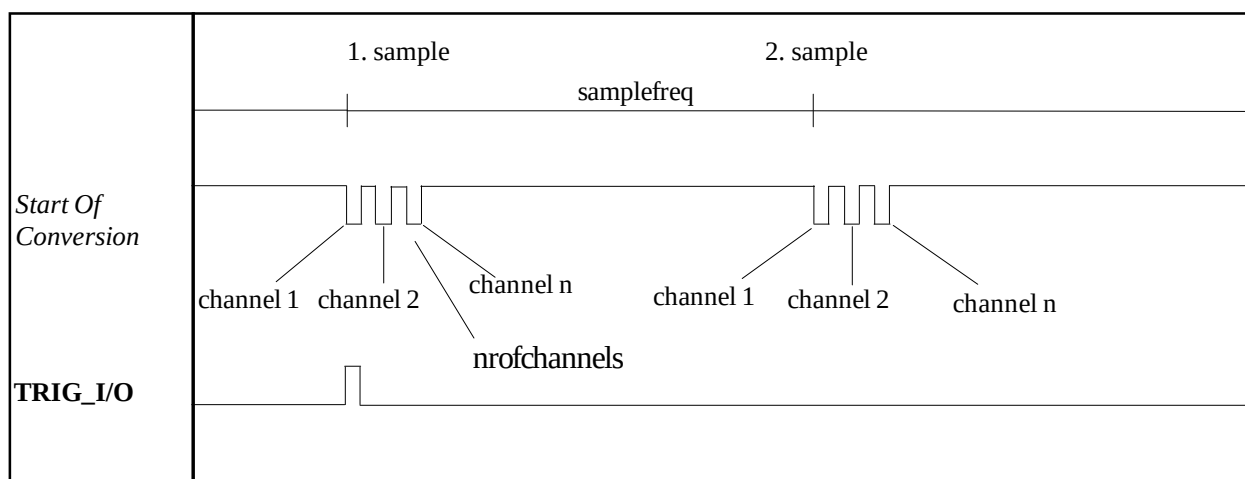
`Mode` describes the operation mode of the AD4-612 board. Master and slave modes are either possible continuously or by single shot. During the master mode, the AD4-612 board starts a pulse to the `TRIG_I/O` port in the beginning of each cycle; during the slave mode, the clock is started by a pulse to the `TRIG_I/O` port. During the continuous mode, the AD4-612 board is started by a single call of the `Start()` function. During the single shot mode, every measurement cycle has to be approved by a further request of the function `Start()`. During the master mode, the conversion starts immediately; during the slave mode, it starts with the next impulse to the `TRIG_I/O` port. The impulse to start the slave mode should not be longer than a sample in order to avoid multiple triggering.

`PauseLength` shows the number of idle cycles between two bursts. The length of the pause is an even integer of `SampleFreq`.

`NrOfSamples` specifies the number of samples in a burst. The distance between two samples is determined by the `SampleFreq` parameter. The delivered value is corresponding with the actual number of samples minus one.

`NrOfChannels` shows the number of sampled channels per sample. The valid range is between one and eight.

The drafts on the following page summarize the relation of the different time parameters.



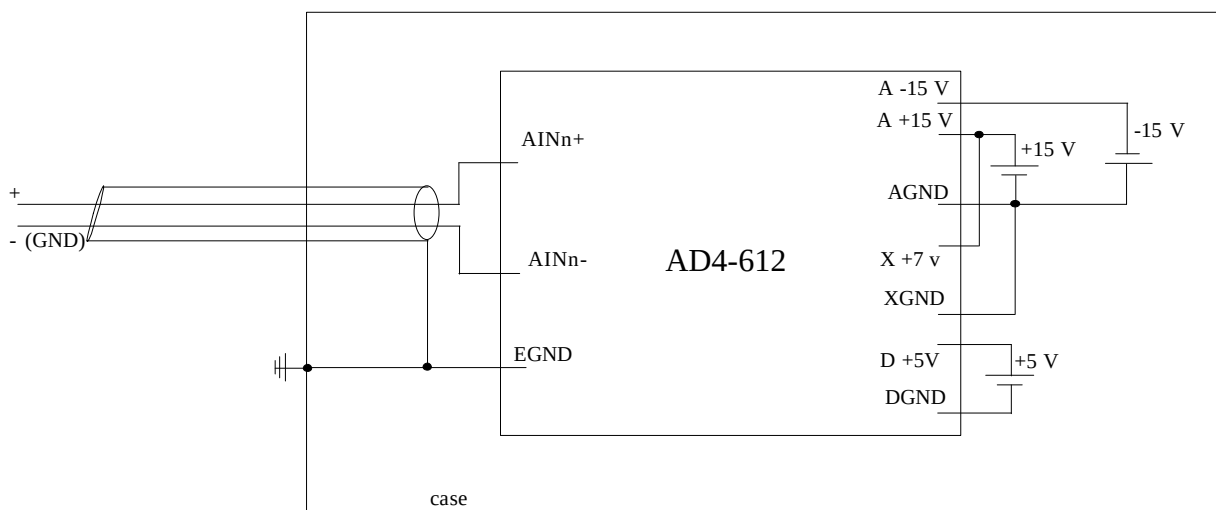
10. Pin-Diagramm

The kind of power supply can be looked up in the diagram. The analog voltage sources should be noise- and potential-free. Here, high-quality DC/DC converters can be used. All voltages should always be started simultaneously (incl. D+5V). The AD4-612 board could be destroyed if there is no complete power supply (in case of devided voltages).

The analog input signals should be transmitted via shielded ports from the signal source to the AD4-612 board. The shield can be connected to the EGND pins of the analog input plug. It is important that the EGND pins of the EGND plug are connected to the case ground and possibly also to the protection ground. If these components are not available, the EGND pins can alternatively be connected to the analog ground (AGND). However, this results in the loss of the ESD (Electro Static Discharge) protection leaving only a simple signal overload protection. In general, it is important, that no system ground loop is built up by the shield. Usually, the shield is only grounded on one side (either on the signal-providing ground or on the AD4-612 ground).

If the signal provider has a differential output, then the +output is connected to the + input of the AD4-612 board. The same applies to the - input. If the signal source has only one ground analog signal and not a differential signal available, the ground of the signal provider should be transmitted together with the wanted signal as -level by the signal cable und be connected to the -input of the AD4-612 board. A direct ground connection between the signal provider and the AD4-612 board should be avoided.

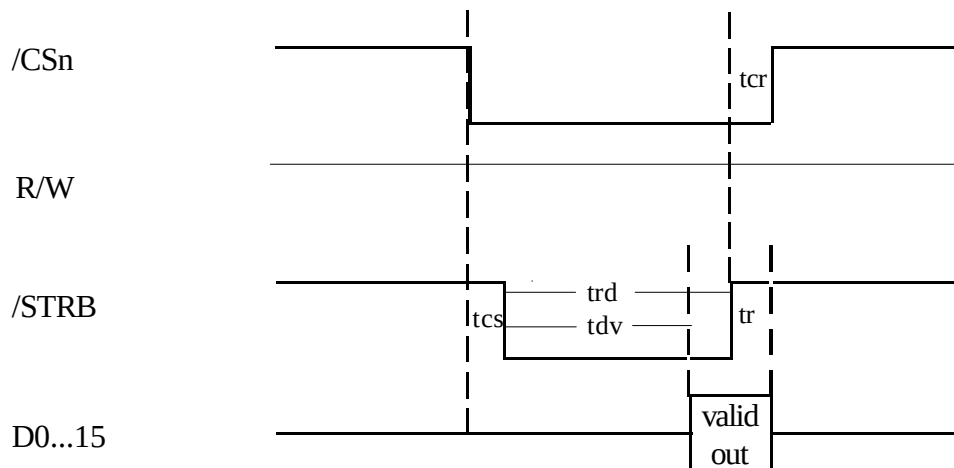
All electric contacts are automatically established when all micro-line® processor modules are plugged together. Here, it is important to have a plug-in connection which is not polarity inverted and not displaced. The 1-pins of all plug rowes should be plugged onto each other and form the ground.



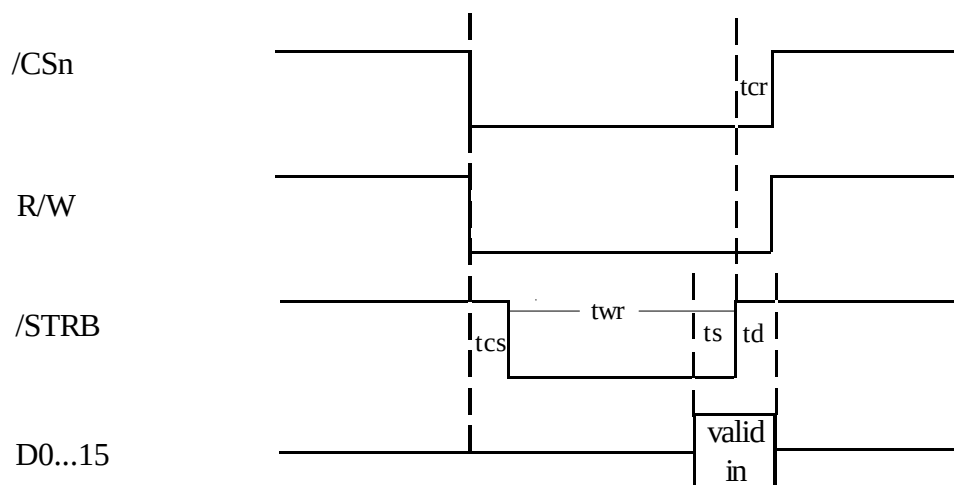
11. Bus-Timing

The following timing parameters are important for data transmission via the micro-line® bus. When using fast processor modules, 1 to 2 waitstates possibly have to be set for data transmission between the AD4-612 board and the processor module. For further information, please refer to the respective processor user's guide.

Read-Cycle:



Write-Cycle:



FPGA-Device

EPM7096LC68-15

t_{cs} (chip select setup time)
 t_{cr} (chip select release time)
 t_{rd} (read cycle time)
 t_{dv} (data valid time)
 t_{r} (data release time)

min. 0 ns
 min. 4 ns
 min. 45 ns
 min. 40 ns
 max. 25 ns

t_{wr} (write cycle time)
 t_{s} (data setup time)
 t_{d} (data hold time)

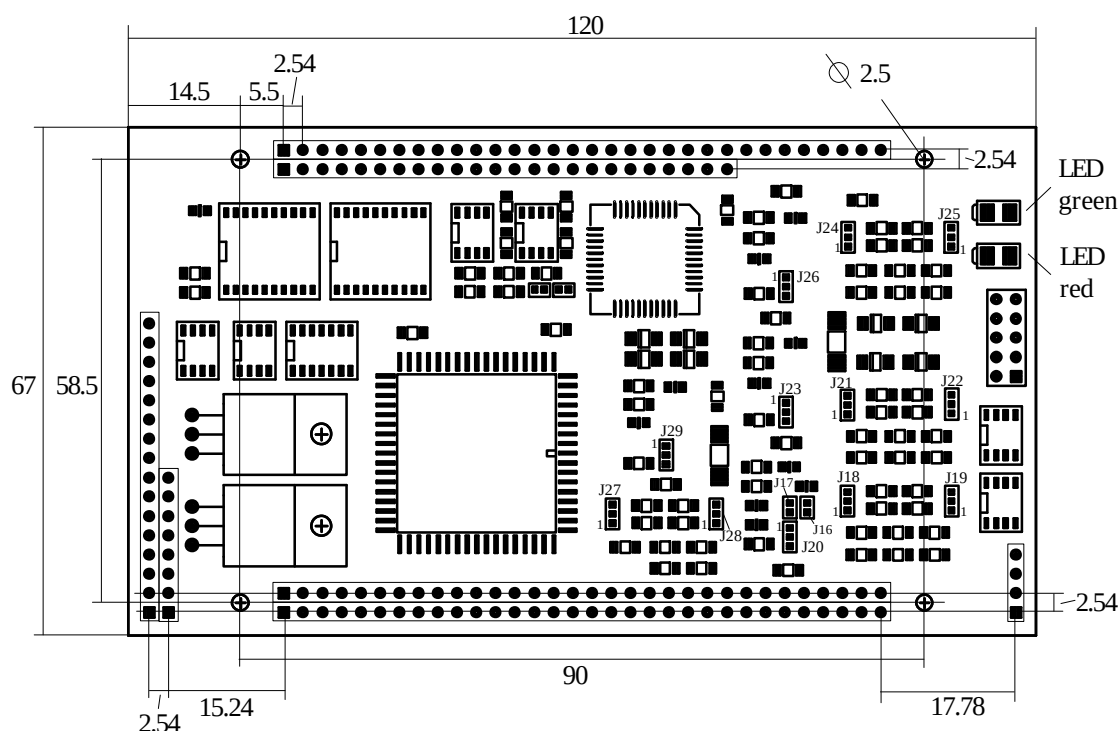
min. 45 ns
 min. 25 ns
 min. 5 ns

12. Power Consumption

The following table shows the characteristic power consumption of the AD4-612 board. Minor alterations depending on the sampling rate and the clock frequency of the connected processor are possible. The entire power consumption of the AD4-612 board is about 5W. Due to the small design, a warming of the AD4-612 board is possible and it is important to have sufficient ventilation. Under normal circumstances, the natural convection is sufficient for cooling. Mandatory ventilation may be necessary depending on the warming of the plugged-on processor module and the size of the used case.

voltage input	voltage range	ch. power consumption
D +5V	4.8 ... 5.5V	200mA
X +7V	7 ... 16V	10mA
A +15V	14 ... 16V	120mA
A -15V	-14 ... -16V	110mA

13. AD4-612 Board Dimensions



14. Ambient Temperature

Storage -25 °C to 80 °C

Operation 0 °C to 70 °C

Extend temperature range available on request.

15. Ambient Humidity

Storage with up to 90 % humidity, not thawing.

Operation with 85 % humidity, not thawing.